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STOMATOCYSTS OF THE DOLINA GĄSIENICOWA VALLEY IN THE TATRA MTS (POLAND). 1. CZARNY STAW GĄSIENICOWY AND ZMARZŁY STAW GĄSIENICOWY LAKES

JOLANTA PIĄTEK

Abstract. Nineteen morphotypes of chrysophyte stomatocysts are reported from Czarny Staw Gąsienicowy and Zmarzły Staw Gąsienicowy lakes in the Dolina Gąsienicowa valley, Tatra National Park, Poland. Of these, four morphotypes are new to science, one is new to Europe, three are new to Poland and one is new to the Tatra Mts. All stomatocysts are documented by original descriptions, SEM micrographs, and information on their Polish and world distribution. The autecology of some stomatocysts found during the present study is reviewed and discussed.

Key words: Stomatocysts, chrysophytes, new morphotypes, taxonomy, autecology, Tatra National Park, Poland

Jolanta Piątek, Department of Phycology, W. Szafer Institute of Botany, Polish Academy of Sciences, Lubicz 46, PL-31-512 Kraków, Poland; e-mail: cabala@ib-pan.krakow.pl

INTRODUCTION

Although several works on chrysophyte stomatocysts have been already published from Europe (Facher & Schmidt 1996a, b; de Hoyos *et al.* 1998; Pla 2001; Pla *et al.* 2003; Kamenik *et al.* 2001; Kamenik *et al.* 2005; Pla & Catalan 2005), this peculiar resting stages of chrysophytes are still insufficiently known in the continent. A few years ago I began systematic work to document the siliceous resting stage of chrysophytes in the Tatra Mts, the highest mountain massif in the Carpathians. This research has produced several notable findings (Cabała 2005a, b; Cabała & Piątek 2004; Piątek 2005).

The Dolina Gąsienicowa valley is large valley in the part of the High Tatra Mts lying in Poland. The valley is surrounded on the west and southwest by peaks of the West Tatras: Kopa Magury Mt., Kasprowy Wierch Mt. and Beskid Mt. South and east of the valley are peaks of the High Tatras, including Świnica Mt., Kozi Wierch Mt. and Żółta Turnia Mt. The Dolina Gąsienicowa valley is divided into two parts separated by the crest of Kościelec Mt. and Mały Kościelec Mt. This area is built of granitic rock and has the largest number of lakes in all the Polish Tatra Mts. The 21 lakes in the Dolina Gąsienicowa valley vary in surface area from the large Czarny Staw Gąsienicowy lake (17.79 ha) to the very small Dwoiśniak lake (0.015 ha). They vary in origin (mainly postglacial but also karstic), the period of ice-cover, and physicochemical parameters (Łajczak 1996; Piątek, unpubl. data).

MATERIAL AND METHODS

CHARACTERISTICS OF STUDY SITES AND THEIR ALGAL FLORA

The material was collected on 5 August 2004 (Fig. 1) at the shores of the lakes, from different microhabitats, including: (i) surface water and water from beneath surface, (ii) sediment from the bottom of the lakes and (iii) water squeezed from mosses. Eight samples were taken from each lake.

1. Czarny Staw Gąsienicowy lake is the biggest lake in the Dolina Gąsienicowa valley, lying at 1620 m a.s.l. It covers 17.79 ha and is 666 m long, 424 m wide and 51 m deep (Radwańska-Paryska & Paryski 1973). The lake is in the subalpine belt and is surrounded by scrub *Pinetum mughi carpaticum*. The surface and bottom of the lake are free of any vascular plant or moss vegetation.

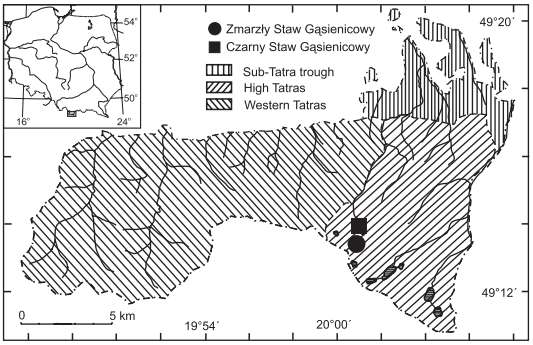


Fig. 1. Location of the study area in Poland and in the Tatra Mts.

Studies on algae in Czarny Staw Gąsienicowy lake were started by Gutwiński (1909), who enumerated a number of algae belonging to various systematic groups. Years later, Wołoszyńska (1919, 1952) recorded various species of dinophytes. Among the taxa she described were two new to science, *Gymnodinium tatricum* Wołoszyńska and *Peridinium tatricum* Wołoszyńska fo. *gracile* Wołoszyńska. Starmach (1934) reported and newly described three taxa of blue-green algae from the lake, *Homeothrix fusca* Starmach, *H. fusca* Starmach fo. *elongata* Starmach and *Chroococcus niger* Starmach. He recorded these algae from various lakes in the Tatra Mts, but did not specify their *loci classici*. During her studies on algae in Tatra lakes, Szklarczyk-Gazdowa (1960) found 16 species in Czarny Staw Gąsienicowy lake, belonging to Cyanophyta, Chrysophyceae, Bacillariophyceae, Dinophyta and Chlorophyta. Lastly, Kawecka and Galas (2003) observed 44 species of diatoms in this lake. The only chrysophyte reported from this lake is *Dinobryon bavaricum* Imhof. (Szklarczyk-Gazdowa 1960).

2. Zmarzły Staw Gąsienicowy lake, also called Zmarzły Staw pod Zawratem lake, is in the east part of the Dolina Gąsienicowa valley, above Czarny Staw Gąsienicowy lake, at 1787 m a.s.l. It is covered by ice and snow until late summer, a fact reflected in its name ('frozen lake'). The lake covers 0.28 ha and is 77 m long, 49.5 m wide and 3.7 m deep (Radwańska-Paryska & Paryski 1973). The lake is in the alpine belt and is surrounded by grassland associations such as *Oreochloo distichae-Juncetum trifidi* and *Luzuletum spadiceae*. The surface and bottom of the lake are free of any vascular plant vegetation, but there are very small patches of moss vegetation in a few places on its bank.

As at Czarny Staw Gąsienicowy lake, studies on algae in Zmarzły Staw Gąsienicowy lake were begun by Gutwiński (1909), who noted numerous algae from various systematic groups. Later on, Starmach (1934) recorded and newly described two taxa of blue-green algae from the lake, *Homeothrix fusca* Starmach and *H. fusca* Starmach fo. *elongata* Starmach. Unfortunately, he reported these algae from various lakes in the Tatra Mts and did not specify which lake was the *locus classicus*. Szklarczyk-Gazdowa (1960) found 27 taxa of diatoms, two species of cyanophytes, and also an unidentified *Mallomonas* sp., the only chrysophyte reported from this lake. In recent years, Kawecka and Galas (2003) recorded 52 taxa of Bacillariophyceae from the lake; they are the best-known group of algae in Zmarzły Staw Gąsienicowy lake.

There are virtually no literature data on stomatocysts occurring in the lakes of the Dolina Gąsienicowa valley. The only information on cysts is that given by Szklarczyk-Gazdowa (1960), who reported observing chrysophytes both as free swimming forms and as cysts in Tatra Mts lakes and included drawings of seven stomatocysts ranging from 7.56 to 16.0 μm in diameter. That paper did not name the lake(s) in which the chrysophyte stomatocysts were observed, nor provide modern descriptions and illustrations to aid in identification. The only modern work on stomatocysts of

Table 1. Chemical and physical characteristics of Czarny Staw Gąsienicowy lake and Zmarzły Staw Gąsienicowy lake in the Tatra National Park.

Chemical and physical parameters	Czarny Staw Gąsienicowy lake	Zmarzły Staw Gąsienicowy lake
Date	5 August 2004	5 August 2004
pH	6.5	6.4
Water temperature °C	12.0	9.0
Oxygen (O_2) mg/l	10.9	10.9
Phosphate (PO_4^{3-}) mg/l	0.25	0.1
Total hardness mmol/l	1.1	1.1
Carbonate hardness (acid-bunding capacity) mmol/l	0.9	0.3
Residual hardness mmol/l	0.017	0.089

the Dolina Gąsienicowa valley describes chrysophyte stomatocysts found in a bryophyte spring on the slopes of Mały Kościelec Mt. (Piątek 2005). The present work initiates a series of papers entitled "Stomatocysts of the Dolina Gąsienicowa valley in the Tatra Mts", reporting the results of studies on chrysophyte stomatocysts in the lakes of this interesting area of the Tatra Mts. The studies are devoted mostly to the taxonomy of chrysophyte stomatocysts in this area, and to a less extent also to their autecology.

CHEMICAL AND PHYSICAL ANALYSIS OF WATER

The chemical and physical characteristics of the water were determined on one occasion, when the samples were collected (5 August 2004), using the Aquamerck® Compact Laboratory for Water Testing (Merck, Darmstadt, Germany). This equipment determines pH, water temperature, oxygen, phosphate, total and residual hardness and carbonate hardness (acid-binding capacity). The tests are based on colorimetric and titrimetric methods, described in detail in the manufacturer's instructions, which can be obtained from the author upon request. The chemical and physical characteristics of the lake water are presented in Table 1.

SAMPLE PREPARATION, MICROSCOPY AND TAXONOMY OF STOMATOCYSTS

Each sample was placed in a glass scintillation vial, covered with 10% HCl (to remove carbonates) and allowed to stand for 24 h, boiled for 15 min, and rinsed several times with distilled water. The samples were covered with 30% H_2O_2 and allowed to stand for 24 h, then boiled for 30 min with a small amount of ClO_3, and rinsed several times with distilled water, with a settling time of 24 h between each aspiration. Finally the samples were slurried in glass vials and covered with 95% alcohol.

For scanning electron microscope (SEM) analysis, another aliquot of each slurry was pipetted onto clean glass, air-dried, and affixed to an aluminium stub with double-sided transparent tape. The stubs were sputter-coated with gold using a CRESSINGTON sputter-coater and viewed with a Hitachi S-4700 with a working distance of *ca* 11.0−12.4 mm. Stomatocysts assemblage and quantitative relationships were estimated in two microscopic holders prepared from each sample (in total sixteenth samples were analysed, i.e. eight samples per a lake), examining cover slips side by side. SEM micrographs were taken in the Laboratory of Field Emission Scanning Electron Microscopy and Microanalysis at the Institute of Geological Sciences of the Jagiellonian University. The stomatocysts were measured and described from SEM micrographs according to International Statospore Working Group (ISWG) guidelines (Cronberg & Sandgren 1986). New stomatocysts not previously published were assigned numbers from Piątek J., beginning with stomatocyst #36, Piątek J., and are cited as 'this paper'.

RESULTS

CHARACTERISTICS OF STOMATOCYSTS

A total of 19 different stomatocysts were recorded from Czarny Staw Gąsienicowy lake and Zmarzły Staw Gąsienicowy lake. The recorded cysts are presented in groups based on their shared morphological characters, following Duff *et al*. (1995) and Wilkinson *et al*. (2001). Number in parentheses following the stomatocysts number and reference indicate the number of SEMs on which each description is based.

UNORNAMENTED STOMATOCYSTS

SPHERICAL, WITHOUT COLLAR

Stomatocyst 9, Duff & Smol 1988 *emend*. Zeeb & Smol 1993 (7) (Fig. 2)

NEGATIVE NUMBER. Zd–60.

LOCALITY. Zmarzły Staw Gąsienicowy lake, bottom sediment and water squeezed from plants.

DESCRIPTION. This stomatocyst is spherical, 6.0–8.0 μm in diameter. The pore is regular, 0.6–0.7 μm in diameter. The cyst body is unornamented.

DISTRIBUTION IN POLAND. Stomatocyst 9 was found in a karstic sink-hole in Staszów (Wołowski *et al*. 2004) and in the Tatra National Park: Staw Toporowy Niżni peat bog (Cabała & Piątek 2004), Staw Toporowy Wyżni peat bog (Cabała 2005a) and Żabie Oko lake (Cabała 2005b).

GENERAL DISTRIBUTION. This stomatocyst has been found in Canada, the U.S.A., Greenland (Duff *et al*. 1995), Central Europe (Facher & Schmidt 1996a, b), Austria (Kamenik *et al*. 2001), the

Spanish Pyrenees (Pla 2001), the high arctic Svålbard lakes (Betts-Piper *et al*. 2004) and southwest Greenland (Pla & Andersen 2005).

Stomatocyst 120, Duff & Smol *in* Duff *et al*. 1992 *emend*. Zeeb & Smol 1993 (5) (Fig. 3)

NEGATIVE NUMBER. Zd–52.

LOCALITY. Zmarzły Staw Gąsienicowy lake, bottom sediment.

DESCRIPTION. This stomatocyst is spherical, 5.8–6.6 μm in diameter. The pore (outer diameter 0.7–0.8 μm, inner diameter 0.5 μm) is regular with a planar pseudoannulus. The cyst body is unornamented.

DISTRIBUTION IN POLAND. Stomatocyst 120 was found in Budzyń peat bog (Cabała 2002), a karstic sink-hole in Staszów (Wołowski *et al*. 2004), Owczary Reserve in sulphuric saline habitats with *Vaucheria dichotoma* (L.) C. Agardh (Piątek & Piątek 2005) and the Tatra National Park: Staw Toporowy Niżni peat bog (Cabała & Piątek 2004) and Staw Toporowy Wyżni peat bog (Cabała 2005a).

GENERAL DISTRIBUTION. This stomatocyst has been found in Canada, the U.S.A., Greenland (Duff *et al*. 1995), Central Europe (Facher & Schmidt 1996a), South Georgia in the subantarctic (van de Vijver & Beyens 1997, 2000), recent sediments of Mallín Book in Argentina (Coradeghini & Vigna 2001), Austria (Kamenik *et al*. 2001), the Spanish Pyrenees (Pla 2001), the high arctic Svålbard lakes (Betts-Piper *et al*. 2004) and southwest Greenland (Pla & Andersen 2005).

Stomatocyst 189, Zeeb & Smol *in* Duff *et al*. 1995 (1) (Fig. 4)

NEGATIVE NUMBER. Zd–32.

LOCALITY. Zmarzły Staw Gąsienicowy lake, bottom sediment.

DESCRIPTION. This stomatocyst is spherical, 7.2 μm in diameter. The pore is regular to slightly conical, 0.7 μm in diameter. The cyst body is unornamented.

NOTES. The hole seen in Figure 4 occurred during preparation of the material.

DISTRIBUTION IN POLAND. Stomatocyst 189 was found in Budzyń peat bog (Cabała 2002), a karstic sink-hole in Staszów (Wołowski *et al*. 2004) and Owczary Reserve in sulphuric saline habitats with *Vaucheria dichotoma* (Piątek & Piątek 2005).

GENERAL DISTRIBUTION. This stomatocyst has been found in Canada, the U.S.A., Greenland (Duff *et al*. 1995), the Spanish Pyrenees (Pla 2001) and the high arctic Svålbard lakes (Betts-Piper *et al*. 2004).

SPHERICAL, SIMPLE CONICAL COLLAR

Stomatocyst 8, Facher E. & Schmidt R. 1996a (1) (Fig. 5)

NEGATIVE NUMBER. Zd–73.

LOCALITY. Zmarzły Staw Gąsienicowy lake, bottom sediment.

DESCRIPTION. This stomatocyst is oval, 12.6 μm wide and 13.5 μm long. The collar is conical and very short, 3.0 μm in diameter. The pore is regular, 0.9 μm in diameter. The cyst body is unornamented.

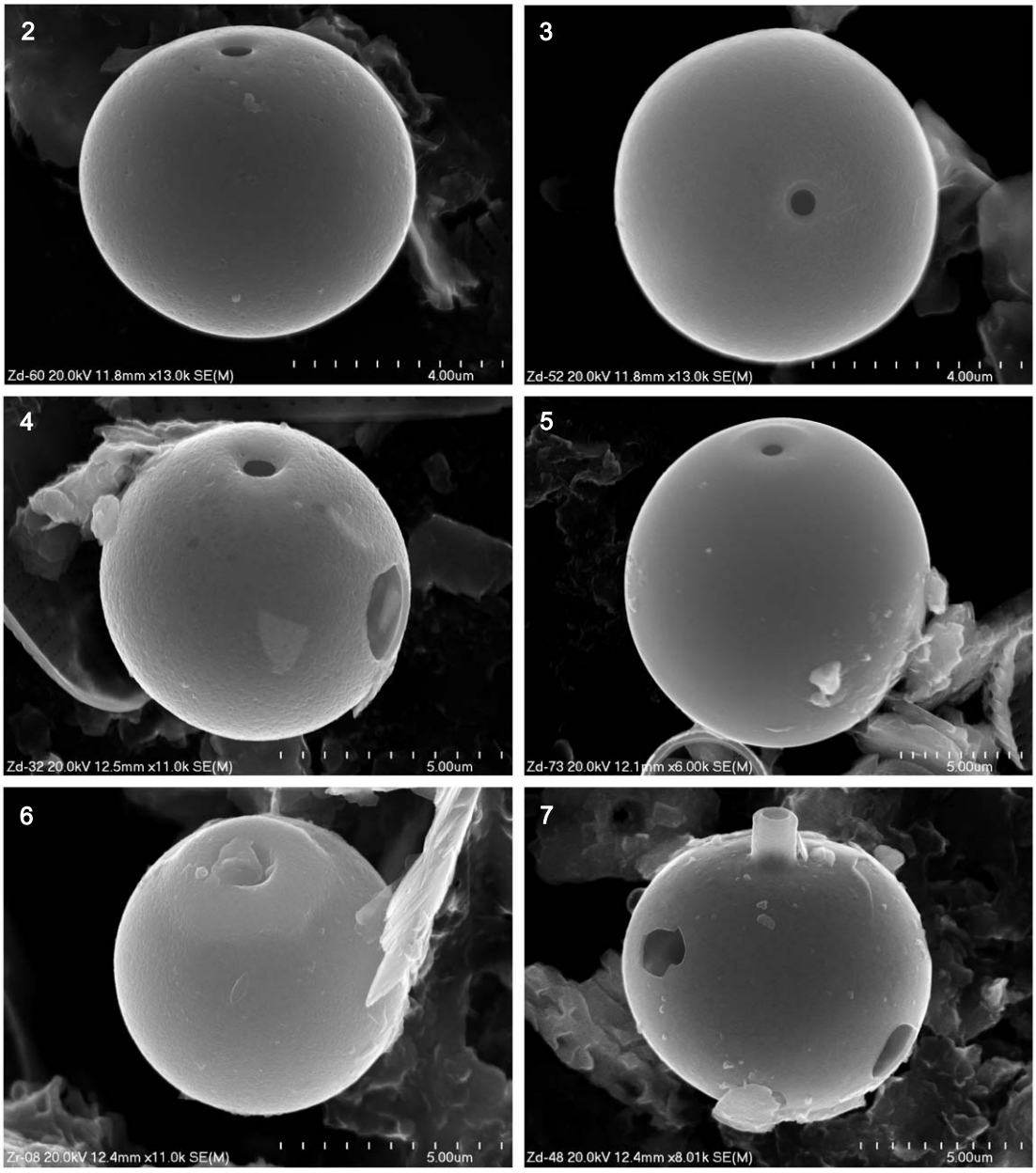
NOTES. This stomatocyst is distinguished from stomatocysts 31 and 33 van de Vijver & Beyens 1997 on the basis of the shape and size of the cyst body and pore. Both stomatocysts are spherical and have a smaller cyst body and pore than stomatocyst 8. Stomatocyst 31 is 9.3 μm in diameter and the pore is 0.46 μm in diameter, whereas stomatocyst 33 is 11.6 μm in diameter and the pore 0.4 μm in diameter.

DISTRIBUTION IN POLAND. Stomatocyst 8 is new to Poland.

GENERAL DISTRIBUTION. This stomatocyst has been found in Central Europe (Facher & Schmidt 1996a).

Stomatocyst 181, Brown & Smol *in* Brown *et al*. 1994 (1) (Fig. 6)

NEGATIVE NUMBER. Zr–08.



Figs 2–7. 2 – Stomatocyst 9; 3 – Stomatocyst 120; 4 – Stomatocyst 189; 5 – Stomatocyst 8; 6 – Stomatocyst 181; 7 – Stomatocyst 428, forma C.

LOCALITY. Zmarzły Staw Gąsienicowy lake, water squeezed from plants.

DESCRIPTION. This stomatocyst is spherical, 6.7 μm in diameter. The collar is conical, 3.7 μm in diameter and 0.5–0.7 μm high. No pore is visible. The cyst body is unornamented.

NOTES. This stomatocyst is similar to stomatocyst 5 Hansen 2001, which is only slightly smaller,

5.9–6.3 μm in diameter. Similarly, stomatocyst 129 Kamenik C. & Schmidt R. (in Kamenik *et al*. 2001) can be distinguished from stomatocyst 181 only by its slightly different size, 6.1–8.6 μm in diameter. The differences in the cyst body measurements of these three stomatocysts (stomatocysts 5, 129, 181) may possibly fall within the normal variability of one morphotype. However, more material should be examined before a final determination.

DISTRIBUTION IN POLAND. Stomatocyst 181 was previously found in Budzyń peat bog (Cabała 2002) and in the Tatra National Park: Staw Toporowy Niżni peat bog (Cabała & Piątek 2004).

GENERAL DISTRIBUTION. This stomatocyst has been found in Canada, the U.S.A., Greenland, Central Europe (Wilkinson *et al*. 2001) and the high arctic Svålbard lakes (Betts-Piper *et al*. 2004).

SPHERICAL, SIMPLE CYLINDRICAL COLLAR

Stomatocyst 428, forma C, Pla & Andersen 2005 (1) (Fig. 7)

NEGATIVE NUMBER. Zd–48.

LOCALITY. Zmarzły Staw Gąsienicowy lake, bottom sediment.

DESCRIPTION. This stomatocyst is slightly oblate, 9.4 μm in diameter. The collar is cylindrical, 1.4 μm in diameter and 1.3 μm high. The cyst body is unornamented. The pore is not visible.

NOTES. The holes seen in Figure 7 occurred during preparation of the material. This stomatocyst is similar to stomatocyst 128 forma A Duff & Smol 1994 *emend*. Wilkinson & Smol 2001, which is larger, 10.0–18.6 μm in diameter.

DISTRIBUTION IN POLAND. Stomatocyst 428 forma C is new to Poland.

GENERAL DISTRIBUTION. This stomatocyst is new to Europe, previously it has been found in southwest Greenland (Pla & Andersen 2005).

Stomatocyst 183, Brown & Smol *in* Brown *et al*. 1994 (4) (Fig. 8)

NEGATIVE NUMBER. Zd–33.

LOCALITY. Zmarzły Staw Gąsienicowy lake, bottom sediment.

DESCRIPTION. This stomatocyst is spherical to slightly oval, 6.0–6.4 μm in diameter. The collar is cylindrical, 1.8–2.1 μm in diameter and 0.3–0.6 μm high, with an irregular apex. The pore is regular, 0.4 μm in diameter. The cyst body is unornamented.

DISTRIBUTION IN POLAND. Stomatocyst 183 was found in Budzyń peat bog (Cabała 2003), and in the Tatra National Park: Staw Toporowy Niżni peat bog (Cabała & Piątek 2004) and Staw Toporowy Wyżni peat bog (Cabała 2005a).

GENERAL DISTRIBUTION. This stomatocyst has been found in Denmark, Canada, Alaska, the U.S.A. (according to Duff *et al*. 1995), the Spanish Pyrenees (Pla 2001), South Georgia in the subantarctic (van de Vijver & Beyens 1997) and southwest Greenland (Pla & Andersen 2005).

Stomatocyst 234, Duff *et al*. 1995 (1) (Fig. 9)

NEGATIVE NUMBER. Zr–09.

LOCALITY. Zmarzły Staw Gąsienicowy lake, water squeezed from plants.

DESCRIPTION. This stomatocyst is spherical, 6.4 μm in diameter. The collar is low and cylindrical, 1.7 μm in diameter and 0.16 μm high. The pore is regular, 0.4 μm in diameter, with a planar pseudoannulus. The cyst body is unornamented.

DISTRIBUTION IN POLAND. Stomatocyst 243 is new to Poland.

GENERAL DISTRIBUTION. This stomatocyst has been found in Canada, the U.S.A., Denmark (according to Duff *et al*. 1995), Central Europe (Facher & Schmidt 1996a, b), South Georgia in the subantarctic (van de Vijver & Beyens 2000), the Spanish Pyrenees (Pla 2001), the high arctic Svålbard lakes (Betts-Piper *et al*. 2004), southwest

Greenland (Pla & Andersen 2005) and Mexico (Vilaclara *et al*. 2005).

Ornamented stomatocysts

with scabrae

Stomatocyst 29, Cabała J. 2005b (1) (Fig. 10)

Negative number. SG/d–13.

Locality. Czarny Staw Gąsienicowy lake, bottom sediment.

Description. This stomatocyst is irregular in shape but slightly pyramidal, 15.1 μm in diameter. The pore is regular, 1.6 μm in diameter. The collar is conical with a rounded apex and sloping inner margin, 4.9 μm in diameter and 0.7 μm high. The cyst body is ornamented with scabrae, 0.1–0.2 μm in diameter, covering the entire cyst body, including the outer collar margin.

Notes. This stomatocyst is distinguished from stomatocyst 388 Pla 2001 on the basis of cyst body size and collar morphology. Stomatocyst 388 is smaller (diameter 6.6–7.4 μm) with an almost cylindrical to slightly conical collar, diameter 1.6–1.9 μm.

Distribution in Poland. This stomatocyst has been found so far only in Poland in the Tatra National Park: Żabie Oko lake (Cabała 2005b), from which it was described as a new morphotype because of its unique size and ornamentation, easily seen by SEM.

Stomatocyst 34, Piątek J. 2005 (2) (Fig. 11)

Negative number. SG/d–8.

Locality. Czarny Staw Gąsienicowy lake, bottom sediment.

Description. This stomatocyst is spherical, 6.2–6.3 μm in diameter. The pore is regular, 0.3 μm in diameter, with a planar pseudoannulus. The cyst body is ornamented with scabrae and verrucae, 0.2–0.3 μm in diameter, covering the entire cyst body except for a depression forming a circulus, 2.8–3.5 μm in diameter, originating from the pore.

Notes. This stomatocyst is distinguished from stomatocyst 92 Facher E. & Schmidt R. 1996a on the basis of ornamentation, pore and collar morphology, and from stomatocyst 310 Pla 2001 on the basis of ornamentation and collar morphology. Stomatocyst 92 has a smooth surface with one circulus originating from the pore, while stomatocyst 310 has a smooth to psilate surface and an eccentric, low and cylindrical collar.

Distribution in Poland. This stomatocyst has been found so far only in Poland in the Tatra National Park, in water squeezed from plants of a bryophyte spring on the western slope of Mały Kościelec Mt. (Piątek 2005).

Stomatocyst #36, Piątek J., this paper (1) (Fig. 12)

Negative number. Piątek J., negative Zd–30. Fig. 12.

Locality. Zmarzły Staw Gąsienicowy lake, bottom sediment.

Description. This stomatocyst is spherical, 6.5 μm in diameter. The pore is regular, inner diameter 0.5 μm, outer diameter 0.9 μm, with a planar pseudoannulus. The cyst body surface is ornamented with regularly scattered scabrae, 0.1–0.2 μm in diameter. No collar is present.

Notes. This stomatocyst is distinguished from stomatocyst 42 Facher E. & Schmidt R. 1996a on the basis of ornamentation and pore morphology. Stomatocyst 42 is ornamented with conula and verrucae, and the concave pore is surrounded by a low collar. Stomatocyst #36 is also similar to stomatocyst 140 Kamenik C. & Schmidt R. (in Kamenik *et al*. 2001), which is, however, ornamented with small verrucae especially on the anterior hemisphere; pore morphology also differs. Moreover, stomatocyst #36 is distinguished from stomatocysts 207 Duff & Smol 1994, 330 Wilkinson & Smol 1998 and 341 Pla 2001 on the basis of the presence of a collar and ornamenta-

tion in form of more irregularly scattered scabrae/verrucae. This stomatocyst is described as a new morphotype because of its unique ornamentation and absence of the collar.

Stomatocyst #37, Piątek J., this paper (2) (Fig. 13)

NEGATIVE NUMBER. Piątek J., negative Zd–26. Fig. 13.

LOCALITY. Zmarzły Staw Gąsienicowy lake, bottom sediment.

DESCRIPTION. This stomatocyst is spherical to oval, 8.5 μm long, 6.4–7.7 μm wide. The pore is regular, inner diameter 0.3 μm, outer diameter 0.5 μm, with a planar pseudoannulus. The cyst body is ornamented with scabrae and verrucae, 0.2–0.3 μm in diameter and 0.2–0.3 μm high, covering the entire cyst body.

NOTES. This stomatocyst is distinguished from stomatocyst 15 Vorobyova *et al*. 1996 on the basis of size, pore morphology and ornamentation. Stomatocyst 15 is smaller (4.5 × 5.2 μm), with a conical pore and cyst body ornamented with bacculate spines. Stomatocyst #37 is described as a new morphotype because of its unique ornamentation and morphology of the pore.

WITH CONULA

Stomatocyst 210, Duff & Smol 1994 (3) (Fig. 14)

NEGATIVE NUMBER. Zd–36.

LOCALITY. Zmarzły Staw Gąsienicowy lake, bottom sediment.

DESCRIPTION. This stomatocyst is spherical, 5.7–6.0 μm in diameter. The pore is regular, 0.3–0.4 μm in diameter. The collar is cylindrical with a flat planar annulus, 1.4 μm in diameter and 0.2–0.5 μm high. The cyst body is ornamented with conula and bifurcating spines, 0.2 μm high and 0.1–0.2 μm in diameter.

NOTES. This stomatocyst was initially classified as stomatocyst 210 Duff & Smol (in Duff *et al*. 1995: Fig. 64), but it differs in pore size and ornamentation. My specimen is very similar to stomatocyst 210 Duff & Smol reported by Pla (2001: Plate P1). This stomatocyst is distinguished from stomatocyst 65 van de Vijver & Beyens 2000 on the basis of size and pore morphology. Stomatocyst 65 is 8.7 μm in diameter and has a conical pore.

DISTRIBUTION IN POLAND. Stomatocyst 210 was previously found in the Tatra National Park: Żabie Oko lake (Cabała 2005b).

GENERAL DISTRIBUTION. This stomatocyst has been found in Canada, the U.S.A., Poland (Duff *et al*. 1995), the Spanish Pyrenees (Pla 2001), the high arctic Svålbard lakes (Betts-Piper *et al*. 2004), southwest Greenland (Pla & Andersen 2005), Slovakian Tatra Mts (Kamenik *et al*. 2005), and Quaternary lake sediments from the Pirin Mts in Bulgaria, reported as 'Chrysophycean stomatocysta' (Ognjanova-Rumenova 2001).

WITH SPINES

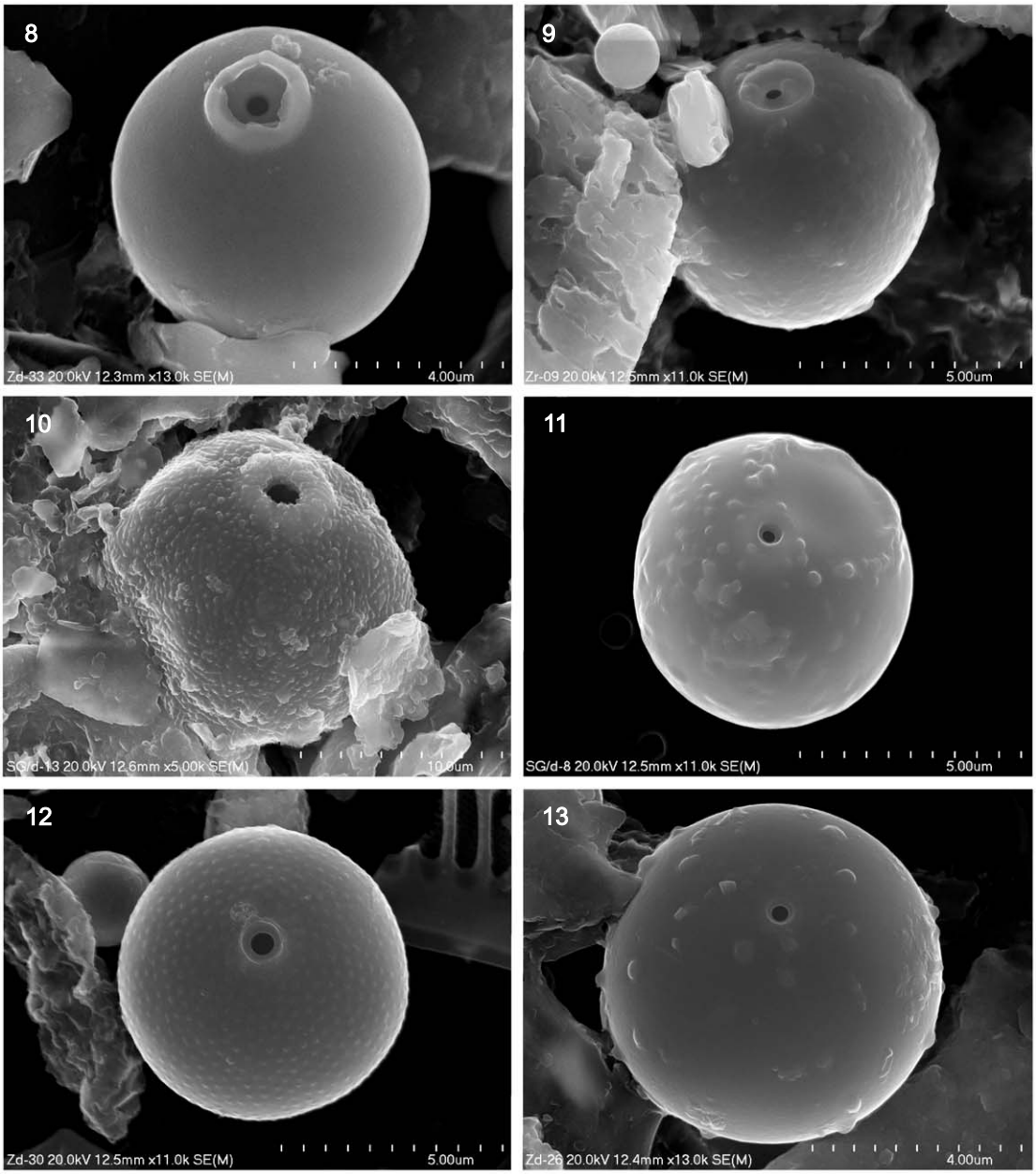
Stomatocyst 73, Duff & Smol 1991 (16) (Figs 15–17)

NEGATIVE NUMBER. Zd–50.

LOCALITY. Zmarzły Staw Gąsienicowy lake, bottom sediment and water squeezed from plants.

DESCRIPTION. This stomatocyst is spherical, 5.8–6.8 μm in diameter. The pore is regular, 0.5 μm in diameter, with a planar pseudoannulus. The collar is cylindrical to obconical, 0.4–0.6 μm high and 1.2–1.4 μm wide, with a curved, highly irregular margin (apex 1.5–2.1 μm in diameter) with siliceous ridges. The cyst body surface is ornamented with short, echinate, bifurcating and bacculate spines, 0.1–0.2 μm in diameter and 0.1–0.3 μm high; numerous spines are found over the entire cyst body surface or in the posterior hemisphere.

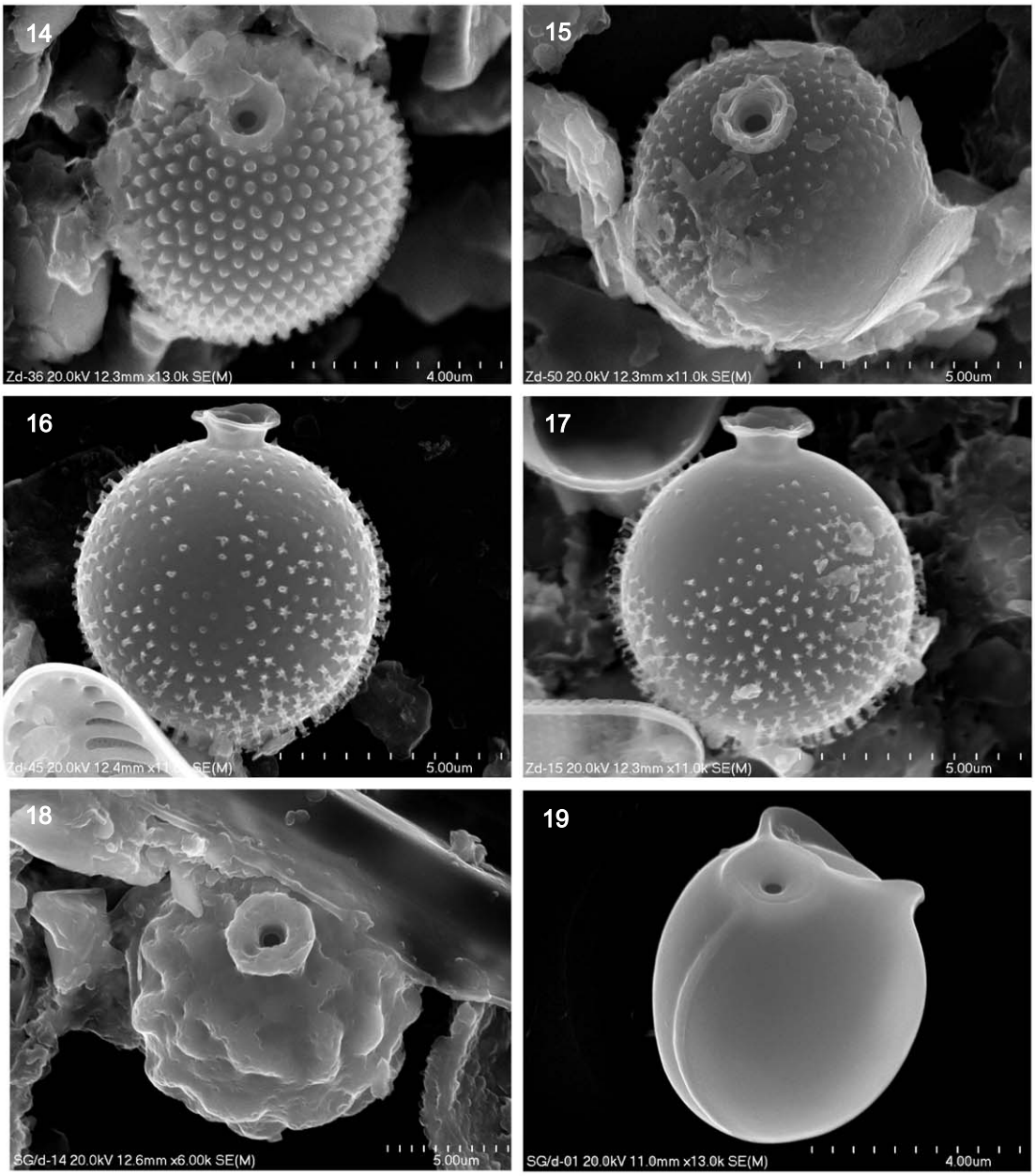
NOTES. The ornamentation of stomatocyst 73 varied between specimens. Most specimens were ornamented with short, echinate, bifurcating and bacculate spines located on the whole cyst body, but some specimens had spines located primarily



Figs 8–13. 8 – Stomatocyst 183; 9 – Stomatocyst 234; 10 – Stomatocyst 29; 11 – Stomatocyst 34; 12 – Stomatocyst #36; 13 – Stomatocyst #37.

in the posterior hemisphere. So, all the SEM micrographs show a different development stage of stomatocyst 73.

DISTRIBUTION IN POLAND. Stomatocyst 73 was previously found in the Tatra National Park: Staw Toporowy Niżni peat bog (Cabała & Piątek 2004) and Staw Toporowy Wyżni peat bog (Cabała 2005a).



Figs 14–19. 14 – Stomatocyst 210; 15–17 – Stomatocyst 73; 18 – Stomatocyst 57; 19 – Stomatocyst #38.

GENERAL DISTRIBUTION. This stomatocyst has been found in Canada, the U.S.A. (Duff *et al*. 1995), Central Europe (Facher & Schmidt 1996a, b), South Georgia in the subantarctic (van de Vijver & Beyens 2000), the Spanish Pyrenees (Pla 2001), Austria (Kamenik *et al*. 2001) and the high arctic Svålbard lakes (Betts-Piper *et al*. 2004).

WITH RIDGES

Stomatocyst 57, van de Vijver & Beyens 1997 (2) (Fig. 18)

NEGATIVE NUMBER. SG/d–14.

LOCALITIES. Czarny Staw Gąsienicowy lake, bottom sediment; Zmarzły Staw Gąsienicowy lake, bottom sediment.

DESCRIPTION. This stomatocyst is spherical, 10.3–11.7 μm in diameter. The pore is regular, 0.7 μm in diameter, with a planar pseudoannulus. The collar is 3.5 μm in diameter. The cyst body is ornamented with irregular, usually lunate ridges which make the surface of this stomatocyst very rough.

NOTES. The specimens reported here have a larger cyst body, pore and collar than in the original description. The measurements given by van de Vijver & Beyens (1997) for their stomatocyst 57 are 9.3–10.5 μm in diameter for the cyst body, 0.44 μm in diameter for the pore, and 2.7 μm in diameter for the collar.

DISTRIBUTION IN POLAND. Stomatocyst 57 was previously found in the Tatra National Park: Staw Toporowy Wyżni peat bog (Cabała 2005a).

GENERAL DISTRIBUTION. This stomatocyst has been found in South Georgia in the Strømness Bay area (van de Vijver & Beyens 1997).

Stomatocyst #38, Piątek J., this paper (6) (Figs 19–20)

NEGATIVE NUMBER. Piątek J., negative SG/d–01. Fig. 19.

LOCALITY. Czarny Staw Gąsienicowy lake, bottom sediment.

DESCRIPTION. This stomatocyst is oval, 5.8–8.5 μm long and 4.7–6.8 μm wide. The pore is regular to slightly conical, 0.3 μm in diameter. The collar is conical, 0.2–0.3 μm high and 1.9–2.3 μm wide. The cyst body is smooth with usually one longitudinal ridge, and two ridges which often form a circulus, 3.2–4.4 μm in diameter, originating from the collar. The longitudinal ridge extends from the collar towards the posterior pole. The ridges are 0.1–0.5 μm high.

NOTES. This stomatocyst is distinguished from stomatocyst 91 Facher E. & Schmidt R. 1996a on the basis of cyst body size and ornamentation. Stomatocyst 91 is larger, 7.0–8.0 × 8.0–10.0 μm, and is ornamented with five or six longitudinal ridges. It is similar to stomatocysts 296 Gilbert & Smol (in Gilbert *et al*. 1997) and 336 Pla 2001, but these have different ornamentation. Stomatocyst 296 has long ridges running from the collar apex towards the posterior pole, while stomatocyst 336 has a smooth to psilate surface with three to five longitudinal ridges.

WITH RETICULUM

Stomatocyst #39, Piątek J., this paper (8) (Figs 21–22)

NEGATIVE NUMBER. Piątek J., negative Zd–38. Fig. 21.

LOCALITY. Zmarzły Staw Gąsienicowy lake, bottom sediment.

DESCRIPTION. This stomatocyst is large and oval to obovate, 11.6–14.1 μm long and 10.6–11.7 μm wide. The pore is regular, 0.8–0.9 μm in diameter. The collar is very low, sometimes resembling a swollen pseudoannulus (Fig. 22), 0.1–0.15 μm high and 1.4–2.3 μm wide. The cyst body is ornamented with fine regular reticulum with small circular lacunae, 0.1–0.3 μm in diameter, usually 0.1 μm in diameter.

NOTES. This stomatocyst is described as a new morphotype because it has a set of unique features such as characteristic ornamentation in the form of regular reticulum with small circular lacunae and characteristic pore and collar morphology. In the available literature, no similar stomatocyst was found except for a cyst described by Nygaard (1956, after Starmach 1968) as ‘cysta scrobiculata’, but that one was significantly smaller, 7.0 μm long and 5.5 μm wide. Starmach (1968) included a line drawing of this cyst, which is not usable for exact identification of ‘cysta scrobiculata’.

WITH COMPOUND ORNAMENTATION

Stomatocyst cf. **143**, Duff & Smol *in* Duff *et al*. 1992 (1) (Fig. 23)

NEGATIVE NUMBER. Zd–49.

LOCALITY. Zmarzły Staw Gąsienicowy lake, bottom sediment.

DESCRIPTION. This is a spherical stomatocyst, 8.9 μm in diameter. The pore and collar are not visible. The cyst body surface is covered by regular to variable reticulum.

NOTES. Although the pore and collar are not visible in the presented SEM micrograph, this specimen seems nearest to stomatocyst 143 by its size and ornamentation.

DISTRIBUTION IN POLAND. Stomatocyst 143 is new to Poland.

GENERAL DISTRIBUTION. This stomatocyst has been found in Canada, the U.S.A (Duff *et al*. 1995), Central Europe (Facher & Schmidt 1996a, b), South Georgia in the subantarctic (van de Vijver & Beyens 2000), the Spanish Pyrenees (Pla 2001), the high arctic Svålbard lakes (Betts-Piper *et al*. 2004) and Mexico (Vilaclara *et al*. 2005).

UNIDENTIFIED STOMATOCYST

Unidentified corroded stomatocyst (20) (Figs 24–25)

NEGATIVE NUMBER. Zd–43.

LOCALITY. Zmarzły Staw Gąsienicowy lake, bottom sediment.

DESCRIPTION. This stomatocyst seems a corroded stage of some cyst. It is more or less spherical and sometimes slightly irregular, 5.4–7.2 μm in diameter. The pore is regular, inner diameter 0.5–0.6 μm, outer diameter 0.7–0.9 μm, with planar pseudoannulus. The cyst body surface is densely psilate or ornamented with small, shallow depressions, 0.1–0.3 μm in diameter. Psilae/depressions are located on the whole cyst body, but denser around the pore. No collar is present.

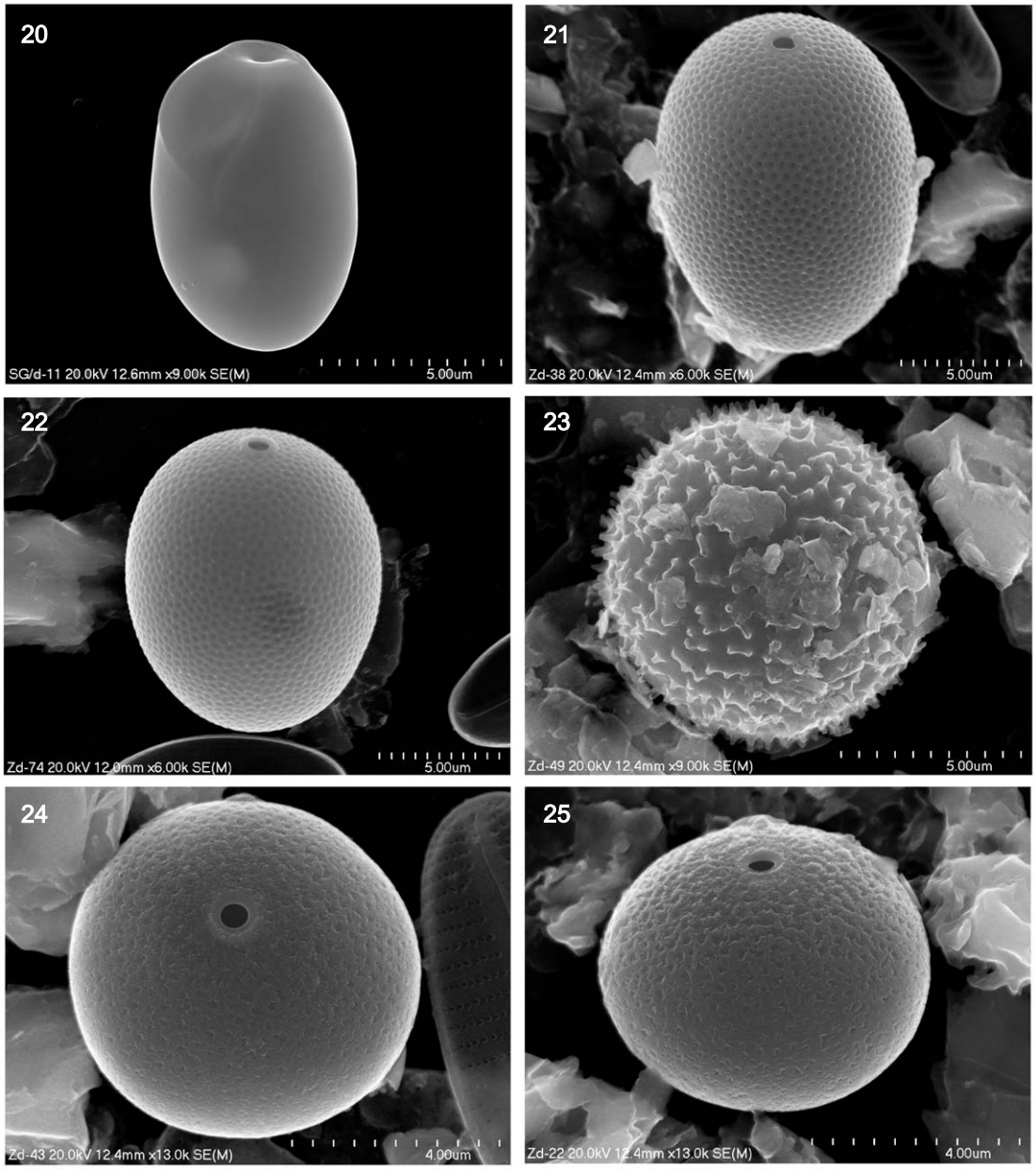
NOTES. According to suggestions of both reviewers this morphotype is probably corroded stomatocyst and its identification to particular cyst type is not possible. So, I did not give any number for this morphotype. It is included here because it occurred most frequently in the stomatocysts assemblage of the Zmarzły Staw Gąsienicowy lake.

STOMATOCYST AUTECOLOGY

The autecologies of numerous stomatocysts were previously characterized *inter alia* by Duff *et al*. (1995), Facher and Schmidt (1996a, b), Pla (2001), Wilkinson *et al*. (2001), Betts-Piper *et al*. (2004) and Pla and Andersen (2005). During present and previous studies, more data have been accumulated for some of them. Therefore, these stomatocysts are discussed here in connection with new autecological observations.

Stomatocyst 8 Facher E. & Schmidt R. was found predominantly in acidic to slightly acidic, high alpine lakes in Central Europe (Facher & Schmidt 1996a). In the present studies, the water where this cyst was found was weakly acidic, suggesting that this stomatocyst may be produced by acidophilic algae. The same applies to stomatocyst 181 Brown & Smol. Betts-Piper *et al*. (2004) included this stomatocyst in the group of cysts that have no ecological characterization. However, stomatocyst 181 was already reported from an arctic tundra lake with oligotrophic water, low (NH_3^+) (5.0 μg/L) and pH 6.3 (Wilkinson *et al*. 2001). In Poland it was found in water with low ammonium (NH_4^+), nitrate (NO_3^-), nitrite (NO_2^-) and phosphate (PO_4^{3-}), with pH 5.0–8.2 (Cabała 2002; Cabała & Piątek 2004, this paper). Facher and Schmidt (1996a) observed this stomatocyst (as cyst 15) only once or twice amongst 18 lakes, and it showed a slight preference for low elevation and strongly acid lakes.

Stomatocysts 9 and 120 Duff & Smol are probably cosmopolitan. Cysts 9 and 120 are well known to be tolerant to pH, temperature and salinity, and are found at many sites in Poland and other regions of the world (see relevant literature



Figs 20–25. 20 – Stomatocyst #38; 21–22 – Stomatocyst #39; 23 – Stomatocyst cf. 143; 24–25 – Unidentified corroded stomatocyst.

in cyst descriptions). Stomatocyst 120 was present in habitats with a broad range of pH, but was more common in lakes with intermediate to higher pH (Betts-Piper *et al*. 2004).

Stomatocyst 428 Pla & Andersen is characteristic for acid lakes, but stomatocyst 428 forma C was more common in alkaline waters (pH > 7) (Pla & Andersen 2005). Similar cyst 189 Zeeb & Smol was strongly associated with oligotrophic, alkaline lakes, and it may be produced by a cold-tolerant

species (according to Duff *et al*. 1995; Pla 2001), but it was more common at higher pH in high arctic Svålbard lakes (Betts-Piper *et al*. 2004). Although it was more commonly observed in lakes, it was also found in peat bog (Cabała 2002) and sulphuric saline habitats (Piątek & Piątek 2005). This latter habitat is unusual for stomatocysts, and occurrence of cyst 189 in such an environment suggests that this morphotype may be saline-tolerant. The specimens found in the sulphuric saline habitats in the Owczary Reserve (Poland) were larger (8.9–10.4 μm) than in the original description (6.0–8.9 μm), but otherwise matched the concept of stomatocyst 189. Pla and Andersen (2005) also shown that cyst 189 is saline-tolerant that reinforce my findings. Up to now, stomatocyst 183 Brown & Smol was more abundant in alkaline waters with high conductivity, but it also occurred along all the conductivity and pH gradients (Pla 2001; Pla & Andersen 2005). Observations from several localities in Poland are relevant to the ecology of this cyst. In Poland this stomatocyst was found associated with *Sphagnum*-dominated peat bogs with weakly alkaline (pH 7.3; Cabała 2002) and mainly weakly acidic waters (pH 5.0–6.4; Cabała & Piątek 2004; Cabała 2005a; this study), suggesting that this cyst may be produced by acidophilic and perhaps epiphytic algae. Stomatocyst 183 was usually present in dystrophic and sometimes in oligo-mesotrophic waters with low conductivity (14–88 μScm^{-1}). These all sites were similar with respect to having very low ammonium (NH_4^+) at 0.0–0.2 mg/l, nitrate (NO_3^-) below the detection limit, nitrite (NO_2^-) 0.0–0.025 mg/l, and phosphate (PO_4^{3-}) 0.0–0.25 mg/l (Cabała 2002, 2005a; Cabała & Piątek 2004).

Stomatocyst 210 Duff & Smol has been reported as an acidophilic, circumneutral or pH-indifferent morphotype (Betts-Piper *et al*. 2004), but it is also considered to be indicator of alkaliphilic and eutrophic conditions (according to Duff *et al*. 1995). Moreover, according to Pla and Andersen (2005) this cyst is more abundant in circumneutral and low conductivity waters. Similarly, in Poland cyst 210 was reported in water with low ammonium (NH_4^+), nitrate (NO_3^-), nitrite (NO_2^-) and phosphate (PO_4^{3-}), with pH 6.4–7.0 (Cabała 2005b; this paper).

Stomatocyst 73 Duff & Smol is tolerant of low pH (< 5.0) and probably of elevated aluminium concentration (Duff *et al.* 1995). It was also found in a lake in the Czech Republic in water with pH optimum 5.24 (Facher & Schmidt 1996b). In Poland it was previously found in the Tatra National Park in waters with pH 5.0–5.5. In Zmarzły Staw Gąsienicowy lake this stomatocyst was relatively abundant and it occurred in pH 6.4, which is larger than hitherto reported data for this stomatocyst.

Stomatocyst 143 Duff & Smol is characteristic of circumneutral to alkaline lakes (according to Betts-Piper *et al*. 2004) and is probably produced by a pH-indifferent taxon (according to Duff *et al*. 1995). In Poland it was found in weakly acidic water (this paper).

There are not enough autecological data for the remaining cysts: 57 van de Vijver & Beyens, 29 Cabała J. (2005b), 34 Piątek J. (2005), #36 Piątek J., #37 Piątek J., #38 Piątek J., #39 Piątek J., and unidentified stomatocyst. These cysts usually occurred in low abundance or singly, and for that reason it is not possible to characterize their autecology at this stage.

Discussion

This study described 19 morphotypes of stomatocysts from Czarny Staw Gąsienicowy and Zmarzły Staw Gąsienicowy lakes. In the stomatocyst assemblage, eight morphotypes were unornamented stomatocysts and eleven were ornamented stomatocysts. Ten of them have been found previously in other parts of the world, including Poland, one is new to Europe, three are new to Poland, and one is new to the Tatra National Park. Four morphotypes, or 21% of all identified morphotypes, are described here as new to science. This proportion of new morphotypes is not surprising in view of the present insufficiency of knowledge about stomatocysts. There are about 700 described morphotypes, and each year new ones are reported. The real number of stomatocysts may be much higher. Based on his own studies of chrysophytes and stomatocysts occurring in the Azores, Hansen (2001) calculated a 0.07 theoretical ratio of silica-scaled species to siliceous cysts, and concluded that in such a situation "... we may expect to be able to

find more than 2600 stomatocyst morphotypes in continental lake sediments, corresponding to the same number of chrysophyte species".

The number of stomatocysts found differed dramatically between the two lakes. Only four morphotypes were detected in Czarny Staw Gąsienicowy lake, and all of them were ornamented: two with scabrae (29 Cabała J. 2005b; 34 Piątek J. 2005) and two with ridges (57 van de Vijver & Beyens 1997; #38 Piątek J.). They occurred extremely rarely, with one or two specimens of each morphotype represented, except for stomatocyst #38, represented by six specimens. In contrast, 16 stomatocysts were found in Zmarzły Staw Gąsienicowy lake, including both unornamented and ornamented morphotypes. Some of them occurred singly (1–3 specimens of each morphotype), others were more common (4–8 specimens), and two were dominant: stomatocyst 73 (16 specimens) and unidentified corroded stomatocyst (20 specimens). It should be pointed out that only one morphotype (stomatocyst 57 van de Vijver & Beyens) was observed in both lakes. Such a divergence of stomatocyst assemblages between the two lakes must be due to a set of factors; the role of a particular factor can be inferred, but cannot be estimated with great certainty. The chemical parameters of the water in the two lakes had very similar values. They were very weakly mineralized and ultra-oligotrophic, with pH 6.4–6.5.

The higher number and higher abundance of stomatocysts in Zmarzły Staw Gąsienicowy lake may also be attributable to the difference in surface area and catchment area between these two lakes. Hansen (2001: 90) observed a clear decrease of the number of morphotypes with increasing surface and catchment area. This hypothesis must be supported by observations in other lakes of the Tatra Mts. It is worth nothing that other groups of algae are represented in these two lakes in similar quantities and abundance; Zmarzły Staw Gąsienicowy lake has a richer algal species composition than Czarny Staw Gąsienicowy lake (Szklarczyk-Gazdowa 1960; Kawecka & Galas 2003).

In terms of water pH, Zmarzły Staw Gąsienicowy lake can be classified as a shallow, moderately acidified lake, where acidophilous organisms such as *Achnanthes marginulata* Grun., *A. helvetica* (Hustedt) Lange-Bertalot and *A. helvetica* var. *minor* Flower and Jones prevail. Czarny Staw Gąsienicowy lake belongs the category of mostly deep, non-acidified lakes, dominated by circumneutral organisms such as *Achnanthes minutissima* Kützing, which has a wide ecological spectrum (Kawecka & Galas 2003). The latter authors reported pH 5.9 for Zmarzły Staw Gąsienicowy lake and pH 6.4 for Czarny Staw Gąsienicowy lake. During the present study the pH values differed slightly from those figures: 6.4 and 6.5, respectively (Table 1). Some recorded stomatocysts may be potential indicators of weakly acidic water, for example stomatocyst 8 Facher & Schmidt or stomatocyst 183 Brown & Smol. However, in these lakes there are also morphotypes, which were reported from other environments: an alkaline stomatocyst (189 Zeeb & Smol), a stomatocyst tolerant of a wide range of water pH from acidic to alkaline (210 Duff & Smol), and mostly cosmopolitan stomatocysts (9 and 120, Duff & Smol).

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REFERENCES

BETTS-PIPER A. M., ZEEB B. A. & SMOL J. P. 2004. Distribution and autecology of chrysophyte cysts from high Arctic Svålbard lakes: preliminary evidence of recent environmental change. *Journal of Paleolimnology* **31**(4): 467–481.

BROWN K. M., DOUGLAS M. S. V. & SMOL J. P. 1994. Siliceous microfossils in a Holocene, high arctic peat deposit (Nordvestø, northwestern Greenland). *Canad. J. Bot*. **72**: 208–216.

CABAŁA J. 2002. Chrysophyceae stomatocysts from Budzyń peat bog (Kraków-Częstochowa Upland, Poland). *Polish Bot. J*. **47**(1): 21–35.

CABAŁA J. 2003. Three morphotypes of chrysophycean stomatocysts from Poland. *Polish Bot. J.* **48**(1): 13–16.

CABAŁA J. 2005a. Chrysophyte stomatocysts from Staw Toporowy Wyżni peat bog in the Tatra National Park, Poland. *Algol. Stud.* **116**: 129–146.

CABAŁA J. 2005b. Chrysophycean stomatocysts from Morskie Oko and Żabie Oko lakes in the Tatra National Park, Poland. *Acta Soc. Bot. Poloniae* **74**(4): 504–514.

CABAŁA J. & PIĄTEK M. 2004. Chrysophycean stomatocysts from Staw Toporowy Niżni lake in the Tatra National Park, Poland. *Ann. Limnol*. **40**(2): 149–165.

CORADEGHINI A. & VIGNA M. S. 2001. Fossil flora of chrysophycean cysts from recent sediments of Mallín Book, Río Negro (Argentina). *Revista Espańola de Micropaleontología* **33**(2): 163–181.

CRONBERG G. & SANDGREN C. D. 1986. A proposal for the development of standardised nomenclature and terminology for chrysophycean statospores. In: J. KRISTIANSEN & R. A. ANDERSEN (eds), *Chrysophytes: aspects and problems*, pp. 317–328, Cambridge University Press, Cambridge.

DE HOYOS C., ALDASORO J. J., TORO M. & COMÍN F. A. 1998. Specific composition and ecology of chrysophyte flagellates in Lake Sanabria (NW Spain). *Hydrobiologia* **369/370**: 287–295.

DUFF K. E. & SMOL J. P. 1988. Chrysophycean stomatocysts from the postglacial sediments of a High Arctic lake. *Canad. J. Bot*. **66**: 1117–1128.

DUFF K. E. & SMOL J. P. 1991. Morphological descriptions and stratigraphic distributions of the chrysophycean stomatocysts from a recently acidified lake (Adirondack Park, N.Y.). *Journal of Paleolimnology* **5**: 73–113.

DUFF K. E. & SMOL J. P. 1994. Chrysophycean cyst flora from British Columbia (Canada) lakes. *Nova Hedwigia* **58**(3/4): 353–389.

DUFF K. E., DOUGLAS M. S. V. & SMOL J. P. 1992. Chrysophyte cysts in 36 Canadian high arctic ponds. *Nord. J. Bot*. **12**(4): 471–499.

DUFF K. E., ZEEB B. A. & SMOL J. P. 1995. Atlas of chrysophycean cysts. *Developments in Hydrobiology* **99**: 1–189.

FACHER E. & SCHMIDT R. 1996a. A siliceous chrysophycean cyst-based pH transfer function for Central European lakes. *Journal of Paleolimnology* **16**(3): 275–321.

FACHER E. & SCHMIDT R. 1996b. Application of chrysophyte sediment trap data and a cyst-based pH transfer function to annually laminated sediments (Lake Plešné, Bohemia, Czech Republic). *Beih. Nova Hedwigia* **114**: 219–231.

GILBERT S., ZEEB B. A. & SMOL J. P. 1997. Chrysophyte stomatocyst flora from a forest peat core in the Lena River Region, northeastern Siberia. *Nova Hedwigia* **64**: 311–352.

GUTWIŃSKI R. 1909. Flora algarum montium Tatrensium. *Bull. Int. Acad. Sci. Cracovie, Cl. Sci. Math.* **34**: 415–560.

HANSEN P. 2001. Chrysophyte stomatocysts in the Azores – biogeographical implications and 110 new morphotypes. *Opera Bot*. **138**: 1–96.

KAMENIK C., SCHMIDT R., KOINIG K. A., AGUSTÍ-PANAREDA A., THOMPSON R. & PSENNER R. 2001. The chrysophyte stomatocyst composition in a high alpine lake (Gossenköllesee, Tyrol, Austria) in relation to seasonality, temperature and land-use. *Beih. Nova Hedwigia* **122**: 1–22.

KAMENIK C., AGUSTÍ-PANAREDA A., APPLEBY P. G., DEARING J. A., SHILLAND E. M., ŠPORKA F., ŠTEFKOVÁ E. & THOMPSON R. 2005. Paleolimnological evidence for atmospheric pollution, climate and catchment-related changes in alpine chrysophyte stomatocyst assemblages (Tatra, Slovakia). *Beih. Nova Hedwigia* **128**: 275–293.

KAWECKA B. & GALAS J. 2003. Diversity of epilithic diatoms in high mountain lakes under the stress of acidification (Tatra Mts, Poland). *Ann. Limnol*. **39**(3): 239–253.

ŁAJCZAK A. 1996. Hydrology. IN: Z. MIREK, Z. GŁOWACIŃSKI, K. KLIMEK & H. PIĘKOŚ-MIRKOWA (eds), *Nature of the Tatra National Park*, pp. 169–196. Tatrzański Park Narodowy, Zakopane – Kraków.

NYGAARD G. 1956. Studies on humic acid Lake Gribsø. The ancient and recent flora of diatoms and Chrysophyceae in Lake Gribsø. *Folia Limnologica Scandinavica* **8**: 32–94.

OGNJANOVA-RUMENOVA N. 2001. Diatom analysis of Upper Quaternary lake sediments from Dulgoto Ezero in Northern Pirin Mountains: I. Taxonomic remarks. *Phytologia Balcanica* **7**(2): 181–194.

PIĄTEK J. 2005. New and rare chrysophycean stomatocysts from the bryophyte spring in the Tatra National Park, Poland. *Polish Bot. J*. **50**(2): 107–116.

PIĄTEK J. & PIĄTEK M. 2005. Chrysophyte stomatocysts of the sulphuric salt marsh in the Owczary Reserve (central Poland). *Polish Bot. J*. **50**(1): 97–106.

PLA S. 2001. Chrysophycean cysts from the Pyrenees. *Biblioth. Phycol*. **109**: 1–179.

PLA S. & ANDERSEN N. J. 2005. Environmental factors correlated with chrysophyte cyst assemblages in low arctic lakes of southweast Greenland. *J. Phycol*. **41**: 957–974.

PLA S. & CATALAN J. 2005. Chrysophyte cysts from lake sediments reveal the submillennial winter/spring climate variability in the northwestern Mediterranean region throughout the Holocene. *Climate Dynamics* **24**: 263–278.

PLA S., CAMARERO L. & CATALAN J. 2003. Chrysophyte cyst relationships to water chemistry in Pyrenean lakes (NE Spain) and their potential for environmental reconstruction. *Journal of Paleolimnology* **30**: 21–34.

RADWAŃSKA-PARYSKA Z. & PARYSKI W. H. 1973. Encyklopedia Tatrzańska. Sport i Turystyka, Warszawa.

STARMACH K. 1934. Über zwei neue Cyanophyceen-Arten aus dem Tatra-Gebirge. *Acta Soc. Bot. Poloniae* **11**(3): 287–297.

STARMACH K. 1968. Chrysophyta I. Chrysophyceae – złotowiciowce oraz wiciowce bezbarwne – Zooflagellata wolnożyjące. IN: K. STARMACH (ed.), *Flora Słodkowodna Polski* **5**. Państwowe Wydawnictwo Naukowe, Warszawa.

SZKLARCZYK-GAZDOWA C. 1960. Phytoplankton of some Tatra lakes. *Acta Soc. Bot. Poloniae* **29**(4): 597–624.

VAN DE VIJVER B. & BEYENS L. 1997. The Chrysophyte stomatocyst flora of the moss vegetation from Strømness Bay Area, South Georgia. *Arch. Protistenk*. **148**(4): 505–520.

VAN DE VIJVER B. & BEYENS L. 2000. Chrysophycean stomatocysts from freshwater habitats of the Strømness Bay area, South Georgia, Antarctica. *Canad. J. Bot*. **78**(1): 88–97.

VILACLARA G., CUNA E. & ZEEB B. 2005. Subfossil chrysophyte cyst morphotypes from two tropical, high-mountain lakes in Nevado de Toluca volcano, Central Mexico. *Beih. Nova Hedwigia* **128**: 309–335.

VOROBYOVA S. S., POMAZKINA G. V., BARANOVA E. YU., LIKHOSHWAY YE. V. & SANDGREN C. D. 1996. Chrysophycean cysts (stomatocysts) from Lake Baikal and Irkutsk. *Journal of Paleolimnology* **15**: 272–277.

WILKINSON A. N. & SMOL J. P. 1998. Chrysophycean stomatocyst flora from southern-central Ontario lakes. *Canad. J. Bot*. **76**(5): 836–862.

WILKINSON A. N., ZEEB B. A. & SMOL J. P. 2001. Atlas of chrysophycean cysts. Volume II. *Developments in Hydrobiology* **157**: 1–169.

WOŁOSZYŃSKA J. 1919. Glony stawów i młak tatrzańskich. Część I. *Rozpr. Wydz. Mat.-Przyr. Akad. Umiejętn., Dział B, Nauki Biol.* **8**: 315–324.

WOŁOSZYŃSKA J. 1952. Bruzdnice Tatr i Karpat Wschodnich. *Acta Soc. Bot. Poloniae* **21**(1/2): 311–316.

WOŁOWSKI K., CABAŁA J. & ZEEB B. A. 2004. Chrysophycean stomatocysts from a karstic sink-hole in the vicinity of the Staszów on the Małopolska Upland, Poland. *Canad. J. Bot*. **82**(9): 1330–1337.

ZEEB B. A. & SMOL J. P. 1993. Chrysophycean stomatocyst flora from Elk Lake, Clearwater County, Minnesota. *Canad. J. Bot*. **71**: 737–756.

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